Water balance mechanisms in the body

ADH is a hormone produced in the brain by the pituitary gland to control the water concentration of the blood. When we sweat during exercise then the concentration of water in the blood is reduced.

After drinking water the blood water concentration increases. The brain detects this change and less ADH is produced. Then the kidney takes an action by reabsorbing less water and therefore more water goes in the urine. This indicates that more volume of dilute urine is produced.

Both the brain and kidneys control the volume of water which has been excreted by the body. If the volume of the blood is low then the concentration of solutes in the blood is high. The brain takes an action to this state by stimulating the pituitary gland to release (ADH) hormone, which indicate the kidneys to reabsorb and circulate the water again. When we need more water, the kidneys will excrete less and reabsorb some.

The pituitary gland which is near the brain checks for the concentration water in the blood and releases the ADH if the blood is short of water. Then the ADH would be flowing in the blood and will not take effect until it gets to the kidneys. If there the ADH is in the blood then the kidneys will go into water by reabsorbing most of the water which is in the tubules and so a smaller volume of urine will be produced. As it still needs to get rid of the water substances, it means that the urine is more concentrated

If there’s no ADH our kidneys would just let the water go and high volume of dilute urine will be produced until the water levels turn back down to normal.

How the kidney uses a counter current mechanism

Inside the renal medulla, capillaries are formed around the tubules. Some of these blood capillaries are thin walled, straight and loop which are the vasa rectae. The blood runs in the opposite directions in the limbs of the vasa rectae. Blood that goes into the renal medulla in the descending limb it comes near the outgoing blood in the ascending limb.

Whilst the blood is flowing to the renal medulla, Na+ and Cl- circulate in the blood. However, as the blood flows to the renal cortex Na+ and Cl- spread out into the interstitial fluid. So this monitors the loss of Na+ and Cl- from the renal medulla then it regulates the concentration of these in the interstitial fluid.

As the filtrate go through the ascending limb of the loop of Henle, sodium chloride is lost into the interstitial fluid in the renal medulla by the process of diffusion. The increase in the concentration of the solutes that is in the interstitial fluid takes water by the process of osmosis from the descending limb as well as the collecting duct. The water that is drawn quickly goes to the vasa recta and is taken away. This regulates the concentration of solutes in the interstitial fluid and aid to turn the isotonic glomerular filtrate to hypertonic urine. The water reabsorption does not occur in the ascending limb this is because its walls are impermeable to water.

Since a large volume of Na+ is lost because of the active transport, the remains again become isotonic. Then water reabsorption occurs through the wall of the collecting tubules, the permeability is regulated by ADH hormone. The secretion of ADH is regulated by the osmotic pressure of the blood. So changing the isotonic filtrate to hypertonic urine is know as counter current mechanism. The urine is approximately 4 times concentrated than the blood plasma in humans.

How the PH is controlled by the kidney

The secretion of further substances which are not needed by the body may take place in the distal convoluted tubule, e. g. hydrogen and hydro carbonate ions. This is very important in the control of plasma Ph, which has to be maintained at 7. 4. If the pH plasma falls, hydrogen ions are excreted by the kidney; if the plasma pH increases hydrogen carbonate ions secreted.

Active Transport

Active transport is the energy-demanding transport of a substance across a cell membrane against its concentration gradient, i. e., from lower concentration to higher concentration.

Special proteins within the cell membrane function as specific protein ' carriers'. The energy for active transport comes from ATP generated by respiration in the mitochondria.

Major examples of Active Transport such as:

- Re-absorption of glucose,
- Amino acids
- Salts by the proximal convoluted tubule of the nephron in the kidney.

A mechanism of active transport moves potassium ions into and sodium ions out of a cell along with protein channel. It is found in all human cells, but is particularly important in nerve and muscle cells. The sodium-potassium pump uses active transport, with energy that is supplied by the ATP molecules, so that it moves 3 sodium ions to the outside of the cell for each 2 potassium ions that it moves in. One third of the body's energy outgoings is used in this process.

Buffer system

Both of the kidneys and the lungs cooperate to regulate a blood pH of 7. 4 by affecting the mechanism of the buffers in the blood. Acid-base buffers present resistance to a change in the pH of a solution when hydrogen ions or hydroxide ions are added or removed. The acid-base buffer normally made of a weak acid, and its base. Buffers starts its function since the concentrations of the weak acid and its salt are large compared to the amount of protons or hydroxide ions which are added or removed.

As protons added to the solution from an exterior source, some of the base component of the buffer is then converted to the weak-acid component. As hydroxide ions are added to the solution protons are ionised from some of the weak-acid molecules of the buffer, converting them to the base of the buffer.

Other buffers function as a minor role than the carbonic-acid-bicarbonate buffer in maintaining the pH of the blood. The phosphate buffer consists of phosphoric acid in equilibrium with dihydrogen phosphate ion and hydrogen ions. The pK for the phosphate buffer is 6. 8, which allows this buffer to work within its best buffering range at physiological pH.

The phosphate buffer only functions as a minor role in the blood, however, because phosphoric acid and phosphate ions are found in very low concentration in the blood. Haemoglobin can also work as a pH buffer in the blood. Protein can reversibly combine either hydrogen ions or oxygen to the protein, but when one of these substances is bound, the other is released.

As we exercise, the haemoglobin assists to regulate the blood pH by combining some of the excess protons which are generated in the muscles and the molecular oxygen is released for use by the muscles.

Types of kidney failue

Kidney failure

The main function of the kidneys is to get rid of the waste product which comes from the body's metabolism. One of the main by-products of the metabolism of the protein is urea. The kidneys will get rid of the waste products by taking them out from the blood and send them along the ureter into the bladder.

If there is a failure in the function of the kidney then the by products builds up in the blood and the body. Very mild levels of azotaemia may give little symptoms, however if the kidney failure continues then the symptoms will occur.

There are two types of kidney failure; one of them is acute renal failure and the other type is: Chronic renal failure.

Acute renal failure

The acute renal failure may appear with any serious illness or operation, mostly those complicated by severe infection. When the blood supply into the kidneys is reduced too much from blood loss, then there will be a drop in blood pressure, severe dehydration or short of salt, which may results damage to the kidneys. If this problem lasts long enough there can be permanent damage to the kidney tissue.

Unexpected blockage to the drainage of urine from the kidney can cause damage as well as kidney stone. Acute kidney damage can occur as a unusual side effect of some medications and other uncommon conditions.

Symptoms of Acute renal failure

Here the symptoms are largely those of the condition causing the kidney failure, such as:

- Blood loss, causing a drop in blood pressure.
- Vomiting and diarrhoea, causing dehydration.
- Crush injuries. If large amounts of muscle are damaged there is a release of toxic protein substances that are harmful to the kidneys.
- Sudden blockage of urine drainage.
- Chronic renal failure

Chronic kidney disease, also called as chronic kidney failure, is a permanent condition which is caused by damages to the kidneys. Chronic kidney disease is a serious condition because our kidneys carry out some important functions within the body, such as filtering by products from the blood and regulating blood flow. The major common cause of this chronic kidney disease is damage caused by other chronic conditions, such as diabetes and high blood pressure.

Symptoms are uncommon unless kidney failure is far advanced, when any of the following may be present:

The symptoms of Chronic renal failure

- Tiredness
- Itching
- Loss of appetite
- Nausea and vomiting
- Breathlessness
- Fluid retention, shown as ankle swelling
- Weakness

Importance to the body to maintain acid base levels

All the cells which make up our body are slightly alkaline and this alkalinity should be maintained in so that it can function properly and remain healthy. However, their cellular activity makes acid and this acid gives the cell energy and function. Since each of the alkaline cell complete its task of respiration, it secrets metabolic wastes and these products of cellular metabolism are acid in nature.

An important property of blood is its amount of acidity or alkalinity. The acidity which is in our body rises when the amount of acidic compounds in the body rise or if the amount of alkaline compounds in the body drop. Alkalinity in our body goes up with the reverse of these processes.

The level of acid or alkaline compounds of any solution, as well as blood will be indicated on the pH scale. The balance of acid-base within the blood is accurately maintained, because even if there is a minor difference from the normal range it would have an effect on various organs. There are different mechanisms that body use to maintain the acid base balance in the blood.

When our body becomes more acidic the body begins to set up resistance mechanisms to prevent the damaging acid from entering our organs. However, if the acid does come to contact with an organ the acid has a possibility to make holes in the tissue which may cause the cell to change in a chromosome or a gene.

The level of oxygen falls in this acidic environment and calcium starts to be at a low level. So as a protection mechanism, our body may actually make fat to protect us from our overly-acidic self. These fat cells may actually be packing up the acid and trying to maintain it a safe distance from our organs to protect them from damage.

Role of the Lungs:

One of the main mechanisms which our body use to maintain the pH of the blood is releasing carbon dioxide from our lungs. Carbon dioxide, which is slightly acidic, is a by product of the metabolism of oxygen and is continuously produced by cells. The by products, carbon dioxide is excreted to the blood.

The blood brings carbon dioxide into the lungs and it is breathed out. As the carbon dioxide builds up in the blood, the blood pH falls. The brain controls the amount of carbon dioxide which is breathed out by maintaining the pace depth of breathing. The amount of carbon dioxide breathed out and as a result the blood pH increases as breathing rate becomes quicker and deeper. By changing the speed and depth of breathing, both the lungs and brain can control the blood pH.

Role of the Kidneys:

The kidneys can also affect pH of blood through the excretion of the excess acids or bases. Moreover, it can change the volume of acid or base which is excreted, however the kidneys make these alterations more slowly than the lungs do, therefore it takes quite a few days.

Buffer Systems:

There is another mechanism which control the pH of the blood is the mechanism of buffer systems, this functions against sudden changes in acidity and alkalinity. The pH buffer systems are groupings of the body's weak acids and weak bases.

These weak acids and bases exist in balance under normal pH conditions. The pH buffer systems start to reduce the changes in the pH of a solution by changing the amount of acid and base. The main pH buffer system within the blood is carbonic acid which is formed by dissolving carbon dioxide in the blood along with bicarbonate ions.

Acidosis and Alkalosis:

- Acidosis: This is when the blood has excess of acid that causes a decrease in the blood pH.
- Alkalosis: This when the blood has excess of base that causes an increase in blood pH.

Acidosis and alkalosis they are actually the result of various disorders. The presence of acidosis or alkalosis gives an important hint to doctors that there is a severe problem exists.

Acidosis and alkalosis are known as metabolic or respiratory. Metabolic acidosis and metabolic alkalosis are as a result of the imbalance in producing the acids or bases and their excretion by the kidneys. Respiratory acidosis and respiratory alkalosis are often caused by the changes in carbon dioxide breathed out because of lung or breathing disorders.

Lactic acid in anaerobic respiration

Lactic acid is commonly used by athletes to describe the severe pain which is felt during extensive exercise, particularly the 400 metres and 800 metres runners. As soon as energy is needed to keep going during exercise, it comes from the breakdown of ATP. The body has a partial store of about 85 grams of ATP and it will be used up quickly if we don’t have ways to reproduce it.

Lactic acid system is able of release energy to resynthesise ATP without oxygen which is known as anaerobic glycolysis. Glycolysis makes pyruvic acid and hydrogen ions. The molecules of pyruvic acid go through oxidation in the mitochondrion and the Krebs cycle begins.

The increase of hydrogen ions will cause the cells of the muscle to become acidic and interfere with their process so a carrier molecule, which is NAD+, take away the hydrogen ions. The nicotinamide adenine dinucleotide is reduced to NADH which put the hydrogen ions at the electron transport gate in the mitrochondria to be joined with oxygen to form water.

If there is inadequate oxygen the NADH will not release the hydrogen ions and they build up in the cell. In order to avoid the increase in acidity, pyruvic acid accepts hydrogen ions to form lactic acid and then dissociates into lactate and hydrogen ions. A few of the lactate circulate into the blood stream and obtain some hydrogen ions with it as a way of decreasing the concentration hydrogen ions in the muscle cell. The normal pH of the muscle cell is 7. 1 however if the increase hydrogen ions continues and pH is decreased to approximately 6. 5 the low pH will stimulate the free nerve in the muscle which causes a pain.

The process of the removal lactic acid takes about one hour, but this can go faster by undertaking the suitable cool down which ensures a fast and constant supply of oxygen to the muscles.

Dehydration and Performance

Many athletes get dehydration during competitions, particularly long distance runners. Dehydration disables both of mental and physical performance in all different types of sport, and it can be minimised by appropriate drinking plan.

Exercise causes body fluid losses from moisture when breathing out air as well as from sweating especially under conditions of high-intensity exercise in high humidity. If fluid losses are not replaced by drinks, sweating causes progressive reduction of circulating blood volume, causing dehydration and a thickening of blood.

This causes a strain on the cardiovascular system, with an increase in heart rate in order to control adequate blood flow to exercising muscles and essential organs. When blood volumes reduced, blood flow to the skin is reduced. Consequently, sweat decreases causing body temperature to rise leading to heat stress.

During intensity exercise, sweat rate rises and it rises by a hot atmosphere and heavy clothing which prevent sweat from evaporating.

Prediction of fluid and sodium losses in sweat is slightly complex, since sweat rates and sweat Na concentrations differs widely between individuals exercising under the same conditions.

Concentration of urine

Urine becomes more acidic as the volume of excess acid retained by the body rises. Alkaline urine, more often contains bicarbonate-carbonic acid buffer, is often excreted when there is an excess of a base or alkali in the body. The secretion of acid and alkaline urine by the kidneys is one of the main mechanisms which the body uses to keep a stable body pH. When we exercise, the ph of the urine becomes more acidic because the acidosis condition has occurred and which is as a result from a build-up of carbon dioxide in the blood, as well as dehydration.

Therefore, exercisers should aim to be well hydrated before they start their training sessions or competitions. The pale yellow urine would indicate a well-hydrated body, but dark yellow urine is a positive sign of dehydration. This is a very visual way of managing the right fluid volume. Checking the colour of urine is much easier than trying to find out the quality of urine.

When the body loses water, the blood becomes more concentrated with sodium and other electrolytes. This activates the thirst mechanism telling the body to enhance fluid intake to regain proper concentrations. However, this mechanism is often unreliable or misread. Older adults also tend to be less sensitive to signals of thirst. Amazingly, most exercisers only replace about 2/3 of the losses from perspiration.

The effect of exercise on body fluid requirements

The optimal pH of the blood is 7. 2 this is essential to run the entire body's biochemical pathways for and general maintenance. The body has different control mechanisms to maintain it at this pH by removing the excess of acid or base by-products via the lungs, saliva and urine.

As the body gets ill the pH is interrupted. Usually our body is trying to regulate the extra acid produced as a result of lack of oxygen, eating lots of protein and carbohydrates foods and by cell breakdown and production of metabolic waste.

As we train and exercise, our muscles use up the oxygen as the chemical energy in glucose is converted into mechanical energy. The oxygen comes from hemoglobin in the blood. During the break down of glucose carbon dioxide and hydrogen ions are produced and then removed from the muscle by the blood. The chemical changes that occur in the blood as a result of the production and removal of carbon dioxide and hydrogen ions along with the use and transportation of oxygen. If the chemical changes are not balanced by other physiological functions, it will cause the pH of the blood to fall.

Acidosis is a condition when the pH of the body gets too low. Acidosis sometimes can be serious this is because the chemical reactions that takes place in the body are pH-dependent. If possible, the pH of the blood should be at 7. 4. If the pH decreases below 6. 8 or increases above 7. 8, it may causes the person to die. However, in our body there are buffers in the blood to protect us from the changes in the pH.

As we exercise the production of carbon dioxide increases through increased respiration in the lungs. As we oxygen is breathed in and carbon dioxide is breathed out, these gases are transported by the blood into the lungs and body tissues. Acids are produced by the body's metabolism that are buffered and then excreted by the lungs and kidneys to regulate body fluids at a neutral pH. Interruption in the levels of carbon dioxide and bicarbonate makes acid-base imbalance. Since this imbalance occurs, the disturbances can be largely divided into either acidosis or alkalosis.

Urine becomes increasingly acidic as the amount of excess acid retained by the body increases. Alkaline urine, usually containing bicarbonate-carbonic acid buffer, is normally excreted when there is an excess of base or alkali in the body. Secretion of acid or alkaline urine by the kidneys is one of the most important mechanisms the body uses to maintain a constant body pH. As we exercise the urine pH becomes more acidic because the condition which known as acidosis have occurred and this results from a build-up of carbon dioxide in the blood, as well as starvation and dehydration.

As we exercise the temperature increases, and the amount of O2 released from the haemoglobin. Heat is a bi product of the metabolic reactions of all cells and the heat released by contracting muscle fibers tends to raise body temperature. Metabolically active cells require more oxygen and liberate more acids and heat.

If we have an increase in temperature, it makes the rate of respiration to increase because oxygen is released from the haemoglobin compared to when the weather is cold. That shows why a person who has fever will breathe quicker than normal person.

In contrast, during hypothermia cellular metabolism slows and the requirement for oxygen is less, and more oxygen remains bound to haemoglobin.

Body Adjustment to improve fitness levels

Exercises help our body to adjust and improve its capacity for physical activities. In order to increase our overall fitness level we have to concentrate on three different areas:

- Cardiovascular training
- Strength training
- Flexibility training

Cardiovascular training

Cardiovascular training is aerobic exercise that involves the large muscles like legs and helps make the heart and lungs stronger. Cardiovascular exercise has lots of health benefits like lowering the blood pressure, and also it can burn lots of calories. This type of exercise leads to improvements in the heart’s ability to pump blood through the body to the working muscles and improves overall cardiovascular health. It is also linked to a number of health improvements including a decreased risk of many diseases, decreases in total cholesterol, blood pressure and levels of body fat.

Strength training

In order to improve our strength, we should increase the weights and the number of sets, otherwise if we lift the same weights, the same way, then we will stay the same – our training is maintenance based. If we want to improve our strength training, then we'll have to make a number of various routines to prevent letting the body become adapted to the current strength training workouts.

We can only strengthen our muscles when they are forced to operate further than its customary intensity. Overload can be progressed by increasing the:

(1) Resistance e. g. adding more weight. (2) Number of repetitions with a particular weight. (3) Number of sets of the exercise. (4) Intensity, i. e. dropping the recovery periods.

Flexibility training

The term flexibility means a joint ability to move through a full range of motion. Flexibility training helps balance muscle groups that may have been exhausted as a result of an extensive exercise. There are several benefits of flexibility training these are:

- Physical Performance is improved.
- Risk of Injury is decreased.
- Increased Blood and Nutrients to Tissues.

Tissue temperature is increased as we stretch and therefore increasing the circulation and transportation of nutrients. As long as the circulation and transportation of nutrients are increased this will allow a better elasticity of surrounding tissues and improves performance.

Maintaining Fluid Balances

Fluid balance is the necessary amount of water present and balanced among the various compartment; this state cannot be separated from electrolyte balance. In the normal conditions water loss is the same as water gain and the water volume of the body remains stable. The body controls the water of our body by the thirst reflex which stimulates us to drink. If water loss is more than water gain the body becomes dehydrated, and dehydration stimulates the thirst reflex in three ways:

- The level of saliva decreases which causes a dry mucosa in the mouth and pharynx;
- There is a rise in blood osmotic pressure which stimulates osmoreceptors in the hypothalamus;
- There is a decrease in blood volume that causes the renin pathway stimulating the thirst centre in the hypothalamus.

When the blood looses excessive fluid dehydration occurs and the blood becomes thicker which causes insufficient blood supply to the working muscles. After exercise the level of body fluids falls down causing an increase in blood tonicity and a reduce in the volume of blood which results in the release of renin in the kidneys and stimulation of osmoreceptors in the hypothalamus. Therefore after exercise, the exerciser must focus on the following areas:

- Effect of drinks
- Cardiovascular and thermoregulatory responses to fluid ingestion
- Carbohydrates feeding and exercise performance

Sports drinks must be formulated to taste best when people are hot and sweaty so that they can drink as much as they possibly can. The sports drinks are absorbed faster than plain water during exercise and rest. During exercise fluid consumption is vital for two primary purposes – safe guarding health and optimizing performance. Therefore, we need to consume more carbohydrate which helps maintaining blood glucose and increases carbohydrate oxidation.

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